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ABSTRACT

Two different uses of computers in instruction are Computer Assisted Instruction (CAI) and Computer Managed Instruction (CMI). CMI is primarily concerned with data management in the instructional process, and CAI is the use of computers to control the instructional process itself. The uses of computers in instruction can be described in four main categories: (1) Drill and Practice, (2) Tutorial-CAI, (3) Games and Simulation, and (4) Computation and Problem Solving. In Tutorial-CAI, instruction is carried out on the computer in a set of frames similar to programmed instruction. The use of computers in the instruction of Adult Basic Education (ABE) students was investigated in two ways: (1) The use of an IBM 1500 System investigated the use of computers for testing, Drill and Practice and Tutorial-CAI, and (2) The development of an Instructional Process Control (IPC) System using a mini-computer and simplified student stations to control response feedback on programmed instructional materials. Conclusions include: (1) ABE pupils found the complexities of the student stations of the IBM 1500 System difficult to master and prone to produce anxiety; (2) The IPC System provided no impediments to learning. Recommendations include: (1) CAI in its conventional forms should not be explored any further at present for ABE pupils; (2) Further demonstration programs should be supported to develop applications of the IPC System. (CK)

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THE APPLICATION OF COMPUTER TECHNOLOGY TO THE INSTRUCTION OF UNDEREDUCATED ADULTS

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ADULT LEARNING CENTER

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ADULT LEARNING CENTER

The Adult Learning Center is an organizational unit in the School of Education at North Carolina State University, and is an integral part of the research and development program of the School of Education.

Established in 1967, the Center is committed to seeking new ways and means for facilitating the intellectual growth and development of adults. The multidisciplinary activities carried out by members of the University faculty associated with the Center are addressed to comprehensive and rigorous studies of the most pressing needs and problems confronting adult education. Among the objectives of the Center is the provision of national leadership in the development and implementation of experimental and demonstration projects which give promise of materially improving adult education programs. A major concern of the Center is the development and dissemination of packaged instructional materials and improved instructional methods which are capable of being institutionalized within operational adult education programs in public school systems.

The Center maintains on the campus of North Carolina State University an adult learning laboratory, the primary purpose of which is to further the use of programmed instructional materials among adults. Continuing research is conducted in the laboratory to determine the capacity of programmed instructional materials to effectively and efficiently raise the educational levels of adults.

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U. S. Department of Health, Education, and Welfare
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ADULT LEARNING CENTER
NORTH CAROLINA STATE UNIVERSITY AT RALEIGH
RALEIGH, NORTH CAROLINA
OCTOBER, 1971

PREFACE

In a rather farsighted article published in 1932, Sidney Pressey observed that nearly every field of human endeavor had been influenced by the industrial revolution except education. Pressey argued that the time had come for educators to relinquish their antiquated practices and begin to explore the utility of mechanical equipment in the classroom. Like it or not, the fact is that since 1932 the industrial revolution has been gradually brought to education. Electronic education is alive and, according to some, doing well.

For a period of almost three years, the Adult Learning Center undertook a research project designed to investigate the effectiveness of computer assisted instruction with functionally illiterate adults. What follows is a report of the findings of the project. It is the hope of the Center staff that this report will substantially contribute to the rapidly-accumulating body of knowledge pertaining to computer assisted instruction. No attempt is made in the report by Dr. Cole to obscure or gloss over failures made in the conduct of the project. As is certainly the case with most innovative projects, mistakes were made. Our hope is that those who read this report will profit by both the accomplishments and failures of the project.

D. Barry Lumsden, Director
Adult Learning Center
October, 1971

TABLE OF CONTENTS

		Page
	INTRODUCTION	1
1.	COMPUTER USES IN INSTRUCTION	3
	CAI and CMI	3
	Types of CAI	4
	Drill and Practice; Tutorial-CAI; Games and Simulation; Computation and Problem Solving	
	The Task of the CAI Division	8
	CAI Costs; Evaluating CAI for ABF Pupils	
	CAI: What the Computer Does	12
	Feedback Control; Branching; Stimulus Control; Data Management; Shared Control	
	The Needs of ABE Pupils	15
	Motivation; Learning Deficiencies	
2.	HISTORY OF THE CAI DIVISION OF THE ADULT LEARNING CENTER	21
	The IBM 1500 System (6/1/67 to 12/1/70)	21
	Minicomputer System (12/1/70 to 6/30/71)	27
3.	RESULTS OF THE OPERATION OF THE CAI DIVISION OF THE ADULT LEARNING CENTER	32
	The IBM 1500 System	32
	System Problems; Results of Use of IBM 1500 System; Costs of Operation	
	The Minicomputer System (IPC)	43
4.	SUMMARY AND RECOMMENDATIONS	52

INTRODUCTION

The purpose of this monograph is to describe the activities of the CAI Division of the Adult Learning Center from the beginning of the Center in June, 1967, to June, 1971, and to report the conclusions and recommendations which have resulted from that activity. During this four year period, the principal source of support for the Center was through authorization of the Bureau of Adult, Vocational, and Technical Education, Division of Adult Education Programs.

The function of the CAI Division of the Adult Learning Center was originally defined by the proposal to the Bureau of Adult, Vocational, and Technical Education as a critical part of the overall mission of the Center: the investigation of the use of modern educational technology for instruction of undereducated adults. The function of the CAI Division is to investigate the feasibility of the use of computers in the instruction of adult basic education (ABE) students.

During the past four years, the CAI Division has investigated a number of ways computers can be used to facilitate the instruction of ABE pupils: (1) testing, (2) tutorial instruction, (3) pupil data management, (4) development of instructional programs, and (5) research on the characteristics of ABE pupils. The bulk of the work has centered on the use of computers for tutorial instruction, and the majority of this report will be concerned with that use. During this four year period, the use of computers in instruction of ABE pupils has been investigated first, through the use of an IBM 1500 System, and second, when the funding for the IBM 1500 System was terminated in

December, 1970, through the use of a minicomputer and specially designed student stations.

This monograph is organized into four chapters: (1) a discussion of computer uses in instruction, (2) a history of the operations of the CAI Division of the Adult Learning Center (1967-71), (3) a report of the results of the operation of the Division, and (4) a summary of the results and a set of recommendations for further research in the use of computers in training ABE pupils.

Computers have been found to be of major utility in the training of ABE pupils, but in a form where the use of the term "CAI" may no longer be appropriate. Because of this, we have coined a new term, IPC, standing for Instructional Process Control, to describe the resultant recommended system. Computers do have an important role to play in an instructional technology for the ABE pupils, but much of the hardware associated with conventional forms of CAI turns out to have a limited utility in the instruction of ABE pupils, especially considering its high cost. IPC is a marriage of the factors of major utility for instruction from both Computer Assisted Instruction and Programmed Instruction, with a significant reduction in the total cost of instruction. The IPC System will be described in detail in the later sections of this report.

CHAPTER 1

COMPUTER USES IN INSTRUCTION

The task of the CAI Division of the Adult Learning Center was the investigation of the uses of computers in the instruction of ABE pupils. Computers may be used in many ways and at many different points in the instructional process. It was neither possible nor desirable for the Adult Learning Center to investigate all aspects of computer usage in instruction. The first job of this monograph will thus be to delimit the task undertaken by the Adult Learning Center by relating that task to the more general problem of the uses of computers in instruction.

CAI and CMI

Two quite different kinds of uses of computers in instruction are Computer Assisted Instruction (CAI) and Computer Managed Instruction (CMI).[1] CAI is primarily focused on the use of computers as an integral part of the instructional process, whereas CMI is primarily focused on the administrative uses of computers in the management of the instructional process.

CMI is primarily concerned with data management in the instructional process and with routine decisions which arise in this data management process. Thus it is concerned with the development of methods of

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[1]The use of CAI and CMI is not consistent in the literature on computer uses in instruction. It is necessary to examine each author's usage carefully to determine what is meant by these expressions. The use of these expressions in this report conforms to majority usage in the literature.

testing, scoring, scheduling, course sequencing and the like. This use of computers in instruction is of obvious importance, especially in contexts where emphasis is placed upon individualizing instruction. If large numbers of pupils are to be guided through individually determined courses of instruction, some form of a computer based data management system becomes necessary for administrative decisions about pupil assignments and resource allocations. Except as an incidental outgrowth of the operation of a CAI system, the Adult Learning Center has not been concerned with CMI.

CAI is the use of computers to control the instructional process itself. There are a number of ways in which the computer can intersect the instructional process. These can be classified into four main categories: (1) Drill and Practice, (2) Tutorial, (3) Gaming and Simulation, and (4) Computing and Problem Solving. Each of these categories will be briefly discussed in order to define more precisely the set of problems undertaken by the CAI Division of the Adult Learning Center. Not all of these instructional uses are equally relevant for the ABE pupil, and the Adult Learning Center has limited its investigations to those uses most likely to benefit instruction of ABE pupils.

Types of CAI

The phrase "Computer Assisted Instruction (CAI)" has been used to refer to a number of different kinds of roles for computers in instruction. These uses of computers in instruction can be described in four main categories: (1) Drill and Practice, (2) Tutorial-CAI, (3) Games and Simulation, and (4) Computation and Problem Solving.

Drill and Practice

In this type of CAI a set of problems is presented to the pupil by the computer one after another on a display device. The pupil enters his solution to each problem through a keyboard, a similar response device, and receives immediate feedback which tells him whether or not his solution is correct. The set of problems for a session is all of the same type, and the practice session contains no instruction.

The computer program operating a session may be of varying degrees of complexity. The problems may be stored in sequence and called one after another. The problems may be generated by the computer by any randomizing process. Records of varying degrees of complexity of pupil performance may be stored within the computer. Decisions may be made by the computer program terminating the session or about the next set of problems the pupil is to receive. These decisions may be based on error statistics of the individual pupil or upon response latencies.

Tutorial-CAI

In this type of CAI, instruction is carried out on the computer in a set of frames similar to programmed instruction. On each frame information is presented to the pupil via a computer controlled student station, which may contain a typewriter, a CRT, a slide projector or a similar display. The pupil enters a response through a device such as a keyboard or a light pen. The computer then evaluates the response and provides the pupil with rapid feedback. This procedure differs from drill and practice in that new material is presented to the pupil on

each frame. Incorrect responses usually elicit some form of remedial activity, even if only a return to the frame with instructions to try again. Differential branching may occur on correct and incorrect answers.

Again, many levels of complexity in the computer program are possible. The level of complexity in the evaluation of the pupil response may vary from a simple evaluation of a multiple choice response to complex matching algorithms which evaluate strings of words generated by the pupil. These matching algorithms may allow for grammatical or spelling errors. Various levels of complexity may be used in gathering data about the pupil's responses from simple records of the pupil's responses to complex statistics based on latencies of response and types of errors. Frames may be presented in a simple linear sequence, or branching techniques may be used with branching based on single responses or upon response statistics.

Most Tutorial-CAI is governed by current practices in the design of programmed instruction. Tutorial-CAI is limited by difficulties in the design of appropriate algorithms for response recognition. Most computer programs will recognize only a relatively simple response, e.g., one or two words. The more complex the system for response recognition, the larger the capacity that is required in the computer. Branching techniques are also limited by computer capacity. Because of the large number of potential frames required for programs which involve much branching, a very large random access storage capacity is required for the computer. A highly sophisticated Tutorial-CAI will require at the minimum a computer with a disk operating system.

Games and Simulation

Instruction may be given in higher order concepts through the use of games and simulation. This use of the computer exploits its interactive capabilities. By interacting with the computer program, the pupil may discover for himself the probable consequences of making various kinds of decisions in complex situations. The pupil determines the parameters which are used to govern a computer program in which the computer output is interpreted as a description of the changing states of some complex system across time. This procedure is especially useful in training involving various kinds of decision-making skills and in helping the student understand dynamic processes.

Computation and Problem Solving

The pupil is taught some computer language or some subset of a computer language in order to gain direct access to the computing power of the system to make calculations or to solve problems. The use of the computing power of the system in this form of CAI is often highly restricted in order to keep the language used by the pupil as simple as possible. Some such use of computational power is sometimes added into the Tutorial or Simulation types of CAI. In more developed forms of this use of computers the pupil will learn higher-order language, like BASIC, which may be used interactively in problem solving tasks. These programming uses of CAI are currently only relevant for advanced pupils, i.e., seniors in high school and above, where mathematical skills are sufficiently advanced to justify the cost of the computational power.

The Task of the CAI Division

CMI was not investigated by the Adult Learning Center because CMI is primarily concerned with administrative and not with instructional uses of computers. Of the four types of CAI, the Adult Learning Center has investigated Drill and Practice and Tutorial-CAI. Gaming and Simulation and Computation and Problem Solving were omitted as not relevant for ABE pupils, who are operating well below high school levels of competency. While the utility of these types of CAI is not ruled out for ABE pupils, the probability of instructional gains with Drill and Practice and Tutorial-CAI was judged to be much higher and thus constituted the first problems for investigation.

Both Drill and Practice and Tutorial-CAI have an obvious application to the instruction of ABE pupils. Although there is no literature directly investigating CAI with ABE pupils, general literature describing the use of these two types of CAI with both children and adults shows that pupils learn at least as well from CAI as from more conventional modes of instruction. If any special advantages can be found for CAI with ABE pupils, the extra investment in developing CAI materials may have high utility.

Two problems determine the direction of development of the investigation: (1) What are the costs involved in operating a CAI installation for the ABE population, and (2) What special advantages might be found for CAI with ABE pupils? The answers to these questions will determine the directions of research and development for CAI with ABE pupils.

CAI Costs

As currently practiced, CAI in any of its forms is expensive, ranging from about $5.00 to $20.00 per pupil/hour when all costs are accounted for. Quotations of lower figures in the literature (down to $0.35 per pupil/hour for the Plato IV System) are all projections which assume a mass use of CAI so that the costs of the development of computer programs, instructional programs, and the costs of computer hardware can be assumed near zero since they are spread over so many users. Under this assumption, most of the cost of CAI becomes the cost of the student terminal. Given costs of terminals of about $2,000.00 amortized over 5 years, and given a utilization of 2,000 hours per year per terminal, the pupil/hour cost of the terminal comes out to about $0.20 per pupil/hour. Whether the additional costs of the system can be assumed to be on the order of $0.15 per pupil/hour depends on the size of the pupil population utilizing the CAI System.

The Adult Learning Center, working with a small pupil population, found that its costs of operating the IBM 1500 System approximated $17.00 per pupil/hour. Using less expensive hardware and a somewhat simplified operating system (for example, a PDP-11 with DOS and 16 CRT terminals), these costs could be reduced without degrading the instructional properties of the system to about $5.00 per pupil/hour, calculated over the same pupil population. While this is a much more reasonable cost, it is still more costly than the operation of more conventional instructional systems by several orders of magnitude. To justify such increased costs it would be necessary to demonstrate that CAI can in

fact bring special benefits to the ABE pupil. These benefits may be either an increase in instructional efficiency so that instructional objectives may be met with fewer contact hours with the pupil, or an increase in instructional quality so that specific learning deficiencies in ABE pupils may be identified and overcome with a resulting general increase in learning abilities of ABE pupils. For maximum gain from the use of computers in instruction, this latter alternative is the most exciting option and will be discussed in detail in the later sections of this report. The IPC System is designed with this specific goal.

The equipment and personnel expenses involved in operating CAI installations also make it important to accomplish the ends of CAI at the lowest possible cost. The tendency in the development of CAI has been to try to put all of the instructional load on the computer. Too often the question has seemed to be, "Can the computer do it?" rather than, "Are instructional objectives helped by having the computer do it?" A result has been the development of the highly costly IBM 1500 System with its sophisticated student stations and its requirements of a large computer memory and extensive bulk storage on tape and disk. Depending upon the requirements of the instructional program, many functions performed by the IBM 1500 System can be performed less expensively by some other device or by the pupil. So far as CAI serves to function as an elegant page-turner, the costs of the system are not justified. Throughout the analysis of the use of computers for the instruction of ABE pupils, the primary question will be, "What can the computer do which is especially effective in the instruction of the

ABE pupil?" Functions in instruction which do not demonstrate special effectiveness for ABE pupils when carried out by a computer will be done by some other, less expensive means.

Evaluating CAI for ABE Pupils

In investigating the uses of computers in instruction of ABE pupils, the Adult Learning Center has limited itself to the study of Drill and Practice and Tutorial-CAI. In evaluating these uses of computers in instruction, the primary reference point will be a comparison between CAI and PI. Tutorial-CAI and PI are highly similar in general format and in their structuring of the instructional process through a sequence of frames, each of which calls for a pupil response. PI, carried out with paper and pencil, is obviously less expensive than CAI, both in development and in operating costs. Any demonstration of special advantages of CAI must show how CAI constitutes a significant improvement over PI.

Project CLUE in its final report (December, 1970) concluded that,

> The benefits unique to computer presentation and control have not yet been isolated....Although the computer may have played a significant role in improvement of instruction by seducing the author into more careful organization, testing, and revision of material, in the end his self-instruction package may be presented to students almost as effectively (and with considerably less time cost) in booklets and audio-visual modules. (p. 14)

This quotation sets the central problem for the use of CAI in the education of ABE pupils. Unless specific instructional gains can be demonstrated for CAI over PI, the additional cost is simply not justified.

In solving this problem, the first step is to examine CAI to see just what the computer is in fact doing, to find out what the computer can do that cannot be done with paper, pencils, and audio-visual modules. Then we may inquire how these additional functions contribute to instruction. This will provide us with a clear framework for evaluating the work of the CAI Division of the Adult Learning Center in its examination of the effectiveness of CAI with ABE pupils.

CAI: What the Computer Does

The number of functions that are carried out by the computer in Tutorial-CAI are quite limited and may be presented in a relatively short list. Evaluating the instructional effectiveness of CAI Tutorial for ABE pupils over PI becomes simply evaluating the instructional effectiveness of these computer functions.

Feedback Control

With CAI, control may be achieved over feedback to the pupil following his response. This control is not possible with PI. The timing of the feedback may be controlled. The immediacy of the feedback, highly important according to some learning theories, is guaranteed, and the pupil cannot anticipate the correct answer as he can by looking ahead in most programmed booklets.

Pupils who are unsure of themselves, especially characteristic of ABE pupils, will not expend the effort to try to generate the correct answer if they can derive it by some easier means, e.g., looking ahead. Forcing the pupil to generate his answer before the feedback is

available forces him to think about what he is doing and increases the motivating function of confirmation.

The nature of the feedback in CAI may be highly complicated. For example, different feedback information may be given every highly probable pupil response. In effect, remedial work can be done within the frame where errors occur, and it can be done on the basis of pupil-generated responses. This cannot be done in a programmed text.

Branching

Branching techniques can be used with a programmed text, e.g., Crowder's scrambled book. If the branching is of any complexity, however, the text becomes nearly unmanageable, the pupil is in serious danger of losing his place in the sequence, and the time to completion of the program is drastically increased. In CAI the branching may become highly complex without increased time to completion and without increasing the load on the pupil, since control of the sequencing is handled by the computer. Under computer control, the branching structure may be invisible to the pupil.

In CAI branching may be based on pupil's constructed responses. A programmed text, to control branching, must use a multiple choice format in which the branch is determined by the choice. In programs where shaping the response is a critical part of the instructional objectives, a multiple choice format is less effective than one based on generated responses.

Stimulus Control

In CAI the materials presented to the pupil are under the direct control of the computer. The pupil cannot review past frames in responding to the present frame unless the computer specifically allows him to do so. If he is to use information presented in previous frames in responding to the present frame, he must use his memory. The demand of memory use within the instructional situation is of great importance in facilitating long term retention of the instructional material. If this demand is not made, the material tends to be insufficiently rehearsed for long term retention, as is shown by the usual drastic decline between immediate and delayed posttest scores with PI materials.

Data Management

The rapid data management facilities made possible by the computer permit immediate on-line evaluation and testing of an instructional sequence as well as immediate evaluation of a pupil's performance. CMI facilities are inherent in the operation of any CAI installation and depend only upon the appropriate program development.

Shared Control

With advanced pupils the control of the instructional sequence may be shared directly with the pupil so that his specific needs may be reflected in the structure and the content of the instructional sequence. The pupil may select alternative sequences by being given explicit choice. The pupil may also be given access to data management

facilities, e.g., access to a dictionary or to a library. Finally, the pupil may be given direct access to the computational power of the computer to solve problems generated by instructional frames.

The Needs of ABE Pupils

The function of the CAI Division of the Adult Learning Center has not been simply to investigate the use of computers in instruction, but specifically to investigate the use of computers in the instruction of ABE pupils. Are there specific instructional needs of ABE pupils which may be met with special advantage by the use of CAI?

To answer this question it is important to begin with a list of the special needs of ABE pupils. It will be this list of needs which will be evaluated against the instructional functions of the computer defined in the preceding section. The special needs of ABE pupils can be discussed in two categories: (1) Motivation, and(2) Learning Deficiencies.

Motivation

Across the ABE population as a whole, ABE pupils are poorly motivated to learn. Some few show high motivation and are currently engaged with existent ABE training programs, but these are very few, constituting about 2 percent of the total estimated ABE population. Many more have had a brief encounter with ABE programs, but drop out almost immediately. If an instructional system is to have an effect by itself on the motivation of ABE pupils, it will be through its ability to retain pupils who have entered the system.

The reasons for the high dropout rate for pupils who enter training programs are not known and probably stem from a variety of reasons. But one general reason can be stated a priori: The total payoff for the pupil for attendance at ABE training classes is not high enough to overcome the costs. An instructional system cannot control the costs to the pupil, but it can control payoff to the pupil. It is at this point that CAI may affect the motivation of ABE pupils.

Low payoff from instruction may be due to a number of factors: (1) Progress may appear to the pupil to be too slow. The pupil may judge that he is not learning enough to justify the time and effort. (2) The instructional process may appear to be aversive to the pupil. He may be made to feel bored, frustrated, overburdened, anxious, etc. (3) The effort involved within the instructional process may appear to be too great. Too much in the instructional process may appear incomprehensible. Although the pupil tests out at the eighth grade level, he may be seriously deficient in some critical skills necessary for performing the current work.

These factors all appear in the actions of ABE pupils working on PI materials at the Learning Laboratory of the Adult Learning Center. Pupils fail to complete programmed instruction materials. They start programs and then drop out. Pupils make very inefficient use of the time spent at the Learning Center. The pupil interaction with the PI materials occurs at a very slow rate, with frequent long pauses, interruptions, side trips, etc. Even though the pupil does not leave the laboratory during a session, he does not stay with a program for any length of time. Twenty minutes actual work on a program in an

hour's visit is a generous estimate. The pupils do not follow instructions very closely. They anticipate correct answers by looking ahead. They tend to skip around in the program, doing easy frames first. The expenditure of effort on instruction is low. Any instructional system such as CAI, which might increase the expenditure of effort on instruction, will produce major gains in the learning of ABE pupils.

Learning Deficiencies

In any instructional procedure, present learning is based on past learning. Pupils cannot respond to PI frames unless they have learned to read and learned to follow instructions. Pupils tend to skip over words they are reading that they have not learned how to pronounce. Pupils cannot respond to requests for information if they neither possess the information nor know where to search for it. Given the very spotty encounters of most ABE pupils with conventional public education, most ABE pupils exhibit many learning deficiencies of this type. Although they are not structurally deficient in learning ability, they do not know what to do when confronted with a learning task; and thus, no matter how highly motivated, fail to perform well enough to maintain the learning activity. A critical job in the instruction of ABE pupils is to identify and to overcome these learning deficiencies. Any major role of CAI and ABE pupils must be centrally directed towards isolating and overcoming these learning deficiencies.

Advantage is attributed to both CAI and PI in the instruction of ABE pupils in that (1) both of these are modes of individualized instruction, and (2) they allow the pupil to proceed at his own pace and to

follow his own needs and interests. In an important sense this argument misses the critical point about both CAI and PI. There are many modes of individualized instruction. A library is one, containing books which can be individually selected for student needs and worked through at the student's own pace, with many kinds of instructional aids, e.g., the card catalogue. CAI and PI are unique not because they are individualized modes of instruction, but because both provide the learner with step by step guidance through the learning process. These are both individualized tutoring procedures. The pupil is not left on his own. Both are instances of tutor (author) controlled learning in which the pupil is given very little range of choice and very little control over the learning process. Any evaluation of either of these modes of instruction should then center on the effectiveness of tutor controlled learning and less time should be spent singing the praises of individualized instruction.

Tutor controlled instruction, whether PI or CAI, assumes that the pupil does not know what to do when confronted with a body of material to learn. The sequence of learning activities of the pupil is then programmed by the tutor. This feature of PI and CAI makes both of these modes of instruction highly important for the instruction of ABE pupils. Above all, the ABE pupil does not know what to do in order to learn something. He not only does not possess the appropriate learning strategies (what to do first, what to do next), he also lacks some of the component behaviors out of which he could build effective learning strategies. To get him to learn a set of materials, it is not only necessary to present him with the material, but he must be guided on

each step through the materials as to what to do next and how to do it. The efficacy of PI or CAI with ABE pupils will depend upon the ability of the instructional program to so guide the learner through the material that he learns how to proceed and what to do. Maximal gains will be made by the pupil insofar as this process teaches him what to do with new materials and teaches him to become an independent learner.

The effectiveness of CAI over PI will in part turn on the ability and willingness of the pupil to follow instructions. If he can and will, then the same kind of job can be done with either CAI or PI; and PI is a great deal cheaper. If he cannot or will not (does not want to), then the greater control possible with some form of CAI will show great payoff in instructional gains. If the pupil is willing but does not know how to follow the relevant instructions, the greater control of CAI may produce large payoffs in shaping the pupil's learning activities until he does find out how to follow instructions. Then he may be transferred to PI materials with great gain. If one is dealing with pupils who can be relied upon to follow instructions exactly and can be relied upon to keep accurate records of what they are doing, then the computer is totally unnecessary, for the pupils can do for themselves nearly everything that the computer might do. But ABE pupils do not have these characteristics.

Maximum gain for the ABE pupil from CAI would be not that he learn any particular materials but that he learn appropriate learning strategies and how to execute them. If the learning strategies are

acquired, the pupil will become a self-learner, the optimum goal of any instructional process.

CHAPTER 2

HISTORY OF THE CAI DIVISION OF THE ADULT LEARNING CENTER

This history extends from June 1, 1967, to June 30, 1971, the full duration of the funding period. The activities of the CAI Division of the Adult Learning Center naturally fall into two parts in terms of the hardware used by the CAI Division: (1) the IBM 1500 System, and (2) the minicomputer system (a LINC computer with simplified student stations). Both phrases of the operation of the CAI Division were a continuous development of the same problems with a change of hardware partly dictated by a loss of funding for the IBM 1500 System. This change also paralleled a total change in the personnel of the CAI Division and a change in the strategy to be used in carrying out the feasibility study. But the primary purpose of the CAI Division of the Adult Learning Center remained unchanged throughout that of evaluating the use of computers in the instruction of ABE pupils.

The IBM 1500 System (6/1/67 to 12/1/70)

The initial development of the specific goals and procedures for the CAI Division of the Adult Learning Center was built around the IBM 1500 System. This system and its associated computer software were in development by IBM in 1967 as their primary entry into the CAI market.

The IBM 1500 System is built around an IBM 1130 CPU with an added peripheral controller, the IBM 1500 as the interface between the CPU and the student stations. The student stations for this system are highly sophisticated, and the completion of the system in 1969

included: (1) a CRT terminal for alphanumeric display with graphics capability and a light pen for pupil responses, (2) a keyboard input associated with the CRT, (3) an IBM Selectric typewriter output for the generation of hard copy for the student, (4) a random access slide projector under computer control, and (5) a random access audio tape input/output under computer control. This student station permitted maximum flexibility in both materials presentation and in the monitoring of pupil responses. The IBM 1500 System is capable of supporting up to 32 student stations. Because of the cost of the student stations, the system used by the CAI Division supported only eight student stations.

Along with the hardware system IBM also provided major software support, primarily an operating system carrying COURSEWRITER, a language developed by IBM specifically for CAI operation of the IBM 1500 System. This total software system is a highly complex operating system, and neither the complexity of this system nor the nature of IBM support was fully understood by the Adult Learning Center prior to the installation of the system.

While IBM provided the DOS and the COURSEWRITER language, the implementation of this system for a particular leased configuration and use is regarded by IBM as the responsibility of the user. This implementation and operation of the system requires a highly trained systems-programmer, not just a programmer skilled in the use of one or another computer language. This was never fully understood by the users, who never acquired a systems programmer with sufficient training and skill to make the system fully operational. Systems problems

disrupted the operation of the CAI Division throughout the period of the lease of the IBM 1500 System, and IBM was blamed for a lack of support which they had never regarded as part of their responsibility. This failure in communications between the users and supplier of the computer hardware and software did not facilitate the operations of the CAI Division.

An additional complication in the operation of the CAI Division in its first year was that the IBM 1500 System promised to the Adult Learning Center was diverted to the Air Force as a higher priority user. Thus, although funding for this operation began on July 1, 1967, the computer was not in house until October, 1968. Since funding for this hardware was withdrawn in December, 1970, the Adult Learning Center had only slightly over two years in which to investigate the use of this equipment and develop programs for ABE pupils.

During more than a year prior to the delivery of the hardware, the CAI Division undertook the training of some of its personnel in the operation of the IBM 1500 System. A full time programmer was hired who studied the operating system and the COURSEWRITER language. Graduate students who were to work with the system were given training in the COURSEWRITER language. Visits were made to operational IBM 1500 centers, especially IBM's own development center, to provide hands-on experience with an operating system and to provide the opportunity to begin development of course material which could be used with the CAI Division's own system when installed.

What was not learned from these visits, since these were visits to operating installations, was the set of systems problems which

inevitably arise in the implementation of the system in a particular hardware and functional configuration. The need for a highly trained systems-programmer could not be detected from these visits because the implementation problems had already been solved in these installations. This produced a highly frustrating (but not predicted) set of problems at the time of installation. Because of the lack of systems experience on the part of the chief programmer for the CAI Division, the solutions to the systems problems were often highly inefficient and the system never became fully operational.

An example of an unsolved systems difficulty may illustrate the effects on research of these problems. When the IBM Selectric typewriters were added to the system, both in the student stations and for proctor use, the buffer space allowed for storing messages to be transmitted to the typewriters was small. When the buffer was filled, an interrupt was generated, all other processing was halted, and the buffer contents were typed out. Since these typewriters type at the rate of 15 characters per second, a line may take as long as four seconds to type. During this time nothing can be transmitted to any student station. Given a number of messages to be transmitted to different typewriters, the delay imposed on the operation of the student stations may at random exceed one minute. Measurement of student response latencies, which within COURSEWRITER should have a resolution of 0.1 seconds, became meaningless. Pupils were subjected to arbitrary and random delays of feedback which seriously disrupted their learning activity. This systems problem was never solved for the duration of the installation.

This criticism should not be taken as a reflection on the Division's chief programmer, who did what she could with the knowledge and skills at her command. If blame attaches anywhere, it should be attributed to the failure to recognize in time the need for a highly-skilled systems-programmer for the operation of this system. Lack of experience with complex computer systems made this recognition unlikely. Further, lack of experience made it impossible for the former Director to correctly evaluate the systems options which were available to him.

Although never fully operational, the system was in operation by October of 1968 with instructional material developed during the preceding year. During the 26 months that followed, additional instructional material was prepared and placed on the computer. All of this material was a translation of linear PI material for use in a Tutorial-CAI. Some of this material had been developed by Center Staff members. Some material was developed as PI in the operation of the PI Division of the Adult Learning Center. Some material, particularly the mathematics sequence, was borrowed from outside sources such as the University of Pittsburgh and adapted to the Tutorial-CAI uses of the Center.

If the Division was to test the feasibility of Tutorial-CAI with ABE pupils, given the restrictions on time imposed not only by the Grant Period but by the late delivery of the hardware and its frequent down-time, then an obvious first move was to get as many courses up as rapidly as possible so that the Division could begin testing ABE pupils on the Tutorial-CAI. Borrowing PI material and translating it into Tutorial-CAI was the most rapid way to do this. Development of materials which more fully exploit the properties of Tutorial-CAI could

wait upon initial testing with PI derived materials. However reasonable this strategy, its consequences were unfortunate. It left the Division open to the charge that its whole CAI operation was simply redundant. The computer was simply being used as a glorified page turner for the operation of PI programs, and $10,000 a month, plus personnel costs, is a large price to pay to turn pages. The funding for the computer was terminated.

During its 26 months of operation the Division did test a number of instructional programs in CAI. During this period all of the ABE pupils in the Learning Laboratory had some training on the CAI System. The results of this training will be discussed below.

Although courses were developed for CAI, the amount of course material developed on the system was limited. This limitation was partly caused by difficulties inherent in COURSEWRITER which were not anticipated by the Division. From the point of view of the author of a course, COURSEWRITER is a very low level language. It provides the skeleton of the course logic and commands for the generation of gross response statistics, but it provides these through an arbitrary and artificial set of coding conventions. Translation of PI into Tutorial-CAI is a very costly operation. It requires many hours of coding of course material into sets of arbitrary symbols, a process which admits of a high error rate and requires extensive on-line debugging of every completed program. Since most authors are subject matter specialists and not computer operators, they do not possess and will not acquire the coding skill. The Division had to add to its staff a number of coding specialists and keypunch operators. By the end of

the second year, eight full-time equivalents were attached to the operation of the IBM 1500 System, not counting instructional programmers. This need for personnel increased the cost of the operation of this system.

Minicomputer System (12/1/70 to 6/30/71)

Following the loss of funding for the IBM 1500 System, it was necessary for the Adult Learning Center to restructure the goals of the CAI Division. This loss of funding also entailed the loss of the specialized personnel associated with the operation and utilization of the IBM 1500 System. At the same time, the CAI Division of the Adult Learning Center moved from its off-campus location to the new School of Education building. This move resulted in the important gain of closer relations with other departments in the School of Education, especially the Department of Psychology. New personnel were introduced into the CAI Division of the Adult Learning Center on a part-time basis to re-examine the goals of the CAI Division and to initiate new lines of development consistent with those goals.

The basis of this new line of development lay in the re-examination of the relationship between PI and Tutorial-CAI. The primary conclusion reached was that for ABE pupils, the essential role of the computer in CAI is control of the feedback for pupil's responses. The focus of the investigation thus began with the properties of this feedback and its control over learner performance. Beginning in the Fall of 1970, a series of pilot studies was initiated to investigate

the minimum computer intervention in PI which would generate the necessary feedback control.

The first series of pilot studies did not use a computer at all. Conventional PI materials were modified to eliminate the student controlled feedback and proctor intervention on each frame was used to provide the necessary feedback. This procedure allowed immediate assessment of the properties of the feedback necessary to control the pupil's learning activities on the PI materials. It was immediately found that the human proctor was too slow. Given the high response rate of the average pupil working with external feedback control on PI material suitable to his educational level, the proctor could monitor the responses of no more than one pupil at a time, and the delivery of feedback for that one pupil was too slow. The delay imposed by the proctor intervention was interpreted by the pupil as interfering with his work on the program and was a source of irritation. In the light of these results, it was necessary to develop some mechanism which would provide the desired feedback control that did not delay the pupil's interaction with his instructional program.

At this point, time was borrowed on a minicomputer belonging to the Department of Psychology at NCSU. This minicomputer is a Classic LINC computer, developed about 1964 by the National Institute of Health for research in biological and behavioral sciences. While the original developmental costs of this machine were high, improved and larger versions of the machine are commercially available currently for a total purchase price of less than $30,000. This is a purchase price which is less than 3 months rent for the full IBM 1500 System. While

this minicomputer does not have the capacity or power of the IBM 1500 System, it does have sufficient capacity and power to monitor pupil behavior and manage feedback control and to store for later retrieval detailed data on student performance. Depending on memory size, such a machine will handle from 4 to 16 pupils simultaneously. Such a small machine thus does have the capacity to do the essential job in monitoring pupil behavior and in controlling feedback.

In developing the utilization of the minicomputer for the study of CAI, it was necessary to take very seriously a major conclusion derived from the analysis of the operation of the IBM 1500 System: Do not ask the computer to do anything that the pupil can do for himself equally well, i.e., without loss of instructional effectiveness.

On the IBM 1500 System one could, and in practice did, ask the computer to do everything. Not only were responses monitored and feedback generated by the computer, but all materials presented to the pupil were stored within the computer and presented by the computer. With less than 1/20th of the memory capacity of the IBM 1500 System and without the very high speed bulk memory provided to the IBM 1500 System by its five disk drives, the LINC computer simply did not have the capacity to do the same jobs. All materials presented to the pupil were presented via booklets and manuals, and the computer's job was restricted to monitoring responses and providing appropriate feedback signals. In effect, this system is a marriage of the high speed feedback control of CAI and the low cost of Programmed Instruction. Because of the degree with which this system deviates from standard Tutorial-CAI, we have coined a separate term to refer to this system.

We will call this system Instructional Process Control (IPC) and refer to the limited computer hardware used in this process control as an Instructional Process Controller.

The IPC is an inexpensive system not only from the point of view of hardware costs, but also from the point of view of development and personnel costs. The development of the IPC from initial conception to initial operation took about two months. Its operation has required the use of a small staff of part-time personnel: 1 computer programmer, 1 research assistant, and 2 materials programmers. None of this staff was employed on more than a half-time basis. Total staffing costs have run significantly below $2,000 per month.

During the last six months of the operation of the CAI Division of the Adult Learning Center, a series of pilot studies have been run using the IPC with four student stations. Pupils for these pilot studies have been drawn from the Learning Laboratory of the Adult Learning Center and from ABE classes operating within Wake County, North Carolina.

Pilot studies have been run to investigate the following problems: (1) the nature of the optimum feedback for the control of the learning activities of ABE pupils, (2) the format of the PI material for optimum use on the IPC, (3) the role of proctor intervention upon the occurrence of multiple student errors, and (4) the use of IPC for on-line development and evaluation of standard programmed materials. Work is presently underway in the modification and further development of PI materials previously developed by the PI Division of the Adult Learning Center. This activity is scheduled for completion in June, 1973.

One outcome of the first pilot study has been the development of a motivating instructional system for the capture and training of hard-core illiterates not being reached by standard ABE programs. The second study has focused primarily on the differential effects on instruction of frame size and generated versus selected responses. As the third study is developing, proctor intervention upon multiple pupil errors is proving to be crucial for the maximum instructional effectiveness of the programmed materials, but within the IPC System proctor intervention is sufficiently minimized so that one proctor can give individual attention to as many as 16 pupils at a time.

CHAPTER 3

RESULTS OF THE OPERATION OF THE CAI DIVISION OF THE ADULT LEARNING CENTER

A report on the results of the operation of the CAI Division naturally breaks down into two sections: (1) operations with the IBM 1500 System and (2) operations with the IPC. The information generated from the operation of these two kinds of computer systems is concerned with quite different kinds of problems in the use of computers in instruction of ABE pupils. Consequently, the results of these two operations will be presented in two sections and will be drawn together in the final section of this report as the basis of recommendations for further lines of development of the use of computers in instruction of ABE pupils.

The IBM 1500 System

During the 26 months of operation of the IBM 1500 System, a number of ABE pupils were tested or trained on the system. These pupils were drawn from the Learning Laboratory of the Adult Learning Center. While most of the time of the pupils in the Learning Laboratory was spent working on standard programmed instruction material, nearly all of these pupils spent some time working on CAI materials presented by the IBM 1500 System.

The materials developed and used on this system included: (1) special programs to familiarize the student with the system and instruction on how to use the student stations, (2) testing materials,

(3) Drill and Practice materials, and (4) Tutorial-CAI materials. A number of segments of Tutorial-CAI courses were used, including extended sequences in mathematics and reading comprehension and many special courses designed for ABE pupils.

System Problems

Before the specific results of the use of these materials with ABE pupils are discussed, a number of general problems in the use of this system with ABE pupils should be described.

As was anticipated, the hardware of this system tended to intimidate ABE pupils. The student stations themselves included a large number of pieces of hardware: CRT with its keyboard and a light pen, a typewriter, a slide viewer, a tape recorder with its headset including both earphones and microphone. This array of equipment was by itself intimidating and even more so was the problem of learning how to interact with each part. Furthermore, the equipment was obviously expensive so that interaction involved some degree of felt risk. On top of this, the computer visibly crouched and operating in the next room was a further source of anxiety.

In order to overcome the student's initial reaction to the system, it was found necessary to do a number of things: (1) The program for introducing the pupil to the system had to be enlarged and made more specific to the kinds of tasks the pupils would perform. (2) A number of special "game" programs were developed to give the pupil extended experience of the operation of the system in a non-threatening and non-demanding context. Various games were developed to exercise different

features of the student stations. (3) The pupils were given some information about computers in order to dispel their anxieties, especially those which centered around the imagery of the "great brain;" and where possible the pupils were allowed to do things to the machine, like changing disks. The sense that they had some control over the device, however limited, did much to dispel anxieties.

A second general problem that arose was that the response modes were too complicated. The response modes included two typewriter keyboards, a light pen, a voice response, all but the latter monitored by the computer. The typewriter keyboards seriously interfered with the pupil's interaction with programmed materials. Instructions to respond based on typewriter key names produced high response errors. The solution to this problem was essentially to abandon use of the keyboard. Some typewriter keys were used to provide the computer with information, but these keys were covered with colored tape and instructions for use were based on key color. This solution solved the problem of high response errors.

Adopting this solution, however, did place a strong constraint on the programmed materials used in this evaluation. The primary response mode used was the CRT light pen. This restricted most programmed materials primarily to response selection rather than response generation. Responses were selected by indicating a choice out of a set of options displayed on the CRT. The effect of this decision on the instructional effectiveness of the programs was not evaluated. The literature on programmed instruction suggests that there is no difference in learning for selected versus generated responses, except in those

contexts where a critical part of the learning is learning to produce the response. Given vocabulary deficiencies in ABE pupils, such response learning may be important.

The COURSEWRITER system, designed for machine-paced instruction, posed another problem. If the pupil fails to respond within some time limit, the program would advance to some remedial frame. This machine pacing was found to be highly aversive for ABE pupils. They reported feeling "rushed" and tended to quit when pushed. As a result of this, machine-paced instruction was abandoned, and each frame was set for exposure for the maximum machine time (16 and 2/3 minutes). While this involved loss of control over what the pupil was doing (e.g., he might have spent ten of those minutes getting a drink of water), it did remove a source of irritation from the system. All programs were then designed to be self-paced with no remediation for long latency responses.

As discussed above, the operating system implemented involved random delays of feedback to the pupil. These random delays were found to be highly aversive for the pupils. Having to wait for the machine to recognize a response was described as extremely irritating. The random delays also led to an unfortunate response strategy on the part of the pupils. Pressing the light pen to the screen did not always produce an immediate reply, so the pupils learned to hold the pen to the screen with their elbow resting on the table. This meant that the pen was removed slowly when the feedback did come. As a result, the pen was sometimes still resting on the screen when the next frame appeared and the computer read this as an answer to that next frame which the pupil had not yet read. This produced an error reply which

was unintelligible to the pupil, and was an additional source of irritation.

During the operation of the IBM 1500 System this random delay was not eliminated. The problem of spurious light pen readings was partially solved by imposing a fixed delay following feedback before the appearance of the next frame. This gave the pupil sufficient time to get his pen away from the screen before the appearance of the next frame.

An additional systems problem was frequent systems failures which terminated the computer operation for varying long periods of time (hours to days). Most of these failures were due to uncaught "bugs" in the operating system for this hardware configuration. These equipment breakdowns were also reported by the pupils to be highly aversive.

These difficulties with the system emphasize the importance of a smoothly running system with ABE pupils. Given their initial anxieties about computers, any frustrating event in interacting with the system generates a strong negative emotional response. Large time-sharing systems with their random delays and frequent line drops would clearly not be a desirable system for ABE pupils unless much training time was invested in overcoming the expected negative emotional reactions. Delay <u>per se</u> is not aversive, and reasonably short delays appear to have little effect on learning. Random delays, on the other hand, where the delay occurrence and duration are unpredictable, do seem to be highly aversive and seriously interfere with the instructional process.

The IBM 1500 student stations generated problems for those ABE pupils with sensory impairments. A number of pupils experienced difficulties in discriminating characters on the CRT display, e.g., + and +. The point-matrix character generation on the CRT raised special problems for pupils with either acuity or astigmatism difficulties. These problems were augmented by the relatively low contrast on the CRT. Problems were also experienced in using the audio I/O for pupils with hearing or ear problems. Some pupils with ear problems could not wear the headsets without discomfort.

While these problems are common in any instructional situation with ABE pupils, the relatively fixed nature of the audio-visual displays generated by the computer system did not permit any solutions for pupils with sensory impairments. For example, text size could not be easily changed. While these problems are all potentially solvable, the cost of solution is high relative to a more flexible medium.

In addition to the other problems, the student carrels containing the student stations were located in one large room. This room was also used by instructional programmers and coders debugging new programs. As a result the noise level was rather high. Pupils reported that this high noise level was seriously disruptive of their work on CAI programs. Effective audio-visual isolation is clearly important with these ABE pupils, more so than is the case with children working with similar equipment. The general tension in the ABE pupil working with this equipment makes him hyper-sensitive to irrelevant stimulation.

Results of Use of IBM 1500 System

Because of the difficulties experienced by ABE pupils in learning to use the student stations, a set of special introductory and demonstration programs was developed. These included an introductory course to familiarize the pupil with the system he would use in his courses, a set of games to reduce anxiety and allow practice with the student stations under non-demanding conditions, and a special program to familiarize the pupil with the operation of the audio unit.

These programs were continually revised as new problems in pupil use of the equipment were encountered. These programs successfully got the pupil over the initial hump in using the IBM 1500 equipment and enabled him to interact appropriately with the other CAI programs.

Testing. A number of diagnostic tests were given to a number of pupils using the computer. These tests included personality, aptitude, and achievement tests. Test scoring is greatly facilitated by using the computer as a testing agency. Immediate analysis of test scores can be generated by the computer.

An analysis comparing scores on tests given by paper and pencil and scores on the same tests given by the computer showed systematic differences. Scores on aptitude and achievement tests were systematically lower when given by the computer. These differences were sufficiently reliable so that correction factors could be worked out for most tests.

It is not known why the scores for the same test given with paper and pencil and by computer differ in this way. Several hypotheses may

be suggested: (1) Tests given by the computer allow access to only one test item at a time. The pupils cannot use information presented in other items to respond to this item. This factor would tend to depress test scores. (2) The awkwardness of the computer response modes for ABE pupils may increase errors in response entries. This factor would also tend to depress test scores. (3) The general anxiety generated by the CAI System may interfere with pupil responses to items. Test scores would be depressed by a spread of attention. This is further confirmed by the pupils' high sensitivity to irrelevant stimuli, such as the high noise level caused by other machines in the testing room.

The on-line testing materials included the Tennessee Self Concept Test, the Bell Adjustment Inventory, the Sullivan Math Placement Test, the ABE Opinion Survey, parts of the Stanford Diagnostic Reading Test, and testing units from the Oakleaf IPI Math Program. For all of these tests, reliability was found unimpaired by conversion to the CAI medium, although a systematic bias was found towards lower scores than in standardized paper and pencil versions of the tests.

Drill and Practice. Because math placement scores came out systematically lower than for equivalent paper and pencil versions, a number of math practice programs were developed. If pupils were given practice on math problems on the computer, their placement test scores were increased. This drill and practice material was thus used primarily as an adjunct to the introductory and familiarization programs for practice in doing math problems on the computer.

Tutorial-CAI. Programs were developed for Tutorial-CAI in the following areas: Math - 16 lessons, Reading - 42 lessons, General -

12 lessons. All of these materials were adaptations of PI materials with appropriate format changes to fit the requirements of the CAI System.

Taking into account the problems discussed previously, all of these programs worked as well as Tutorial-CAI, as did their PI counterparts. Tutorial-CAI is a useful instructional medium for ABE pupils.

The laboratory facilities provided an ideal situation for comparative studies of similar CAI and PI materials. Unfortunately, the mode of data collection is such that these comparisons cannot be made. There are no data on times to completion or on pre-test to post-test gains for both the PI and CAI versions of the same instructional materials. It is thus not possible to draw conclusions about the relative efficiencies of the two media for the presentation of instructional materials to ABE pupils. All that is known is that ABE pupils successfully completed course materials in both media.

A questionnaire was devised to assess student attitudes toward various aspects of the CAI System, but this questionnaire did not inquire directly about preferences of CAI over PI. The only relevant information in the questionnaire was that most pupils believed one hour a day with CAI was sufficient. This does not suggest that they preferred CAI to PI. The data from the questionnaire suggest that although pupils learned to work with the CAI System, the initial aversiveness of the system was never fully overcome.

The development of the Tutorial-CAI materials consumed a large amount of computer time. COURSEWRITER is a low level computer language and requires time-consuming coding to get the program into the machine. The artificiality of this coding system leads to a high probability of

coding errors with a corresponding time-consuming job of on-line debugging of entered programs. Of the eight student stations in the system, between two and three were continually in use by authors and coders debugging and modifying programs. This meant that the system was at most handling only about six students at a time.

Costs of Operation

The cost of operating the IBM 1500 System was excessive. Combined personnel and hardware costs totaled $100 per hour. Since the system was serving at most about six pupils at a time, the pupil/hour cost was about $17.00. However this is calculated, this is expensive instruction.

The costs of program development were high, even though most of the Tutorial-CAI materials were translated from PI materials. In the preparation of Tutorial-CAI from existent PI materials, the format must be changed to fit the requirements of the computer system. Primarily this meant a change in the response mode, usually to multiple-choice format to allow the use of the light pen as the response device. For some programmed materials this meant rather extensive changes in program structure. The coding costs for COURSEWRITER have already been described.

A serious difficulty with the current state of CAI is that even small differences in CAI installations require time-consuming modifications to programs to get them to run properly on a system other than the one for which they were designed. Compatibility between different CAI systems is poor. Unless the necessary translations have

been worked out to allow one system to accept programs from another system, the extent of use of the materials developed at one installation will be quite limited. Thus, it is highly important that standardization procedures be developed to allow higher compatibility between different CAI installations. If this is not done, all development costs must be absorbed by the developing installation. So long as the present diversity of hardware configurations and computer languages persists, CAI will continue to carry a very high price tag.

In evaluating the $17.00 per pupil/hour cost of the operation of the IBM 1500 System, two factors need to be considered:

First, the operation of the IBM 1500 System was a research operation. This hardware, though costly to operate, does possess a high degree of flexibility and sophistication. It is an excellent research tool. For CAI operation, as contrasted with research and development, a much less sophisticated machine will do the job. By using a minicomputer with DOS, a system can be designed which will cost less than $0.50 per pupil/hour in contrast to the $10.00 per pupil/hour for the IBM 1500 System. Such a system will not support all of the options on the IBM 1500 System, but it will as an operating CAI System do everything that the IBM 1500 System will do in Tutorial-CAI.

Second, in a production installation the system would be serving more than six pupils at a time and, given the satisfaction of compatibility requirements, the developed materials would be serving more than one installation. Both of these factors would tend to distribute production costs and reduce the current cost of $7.00 per pupil/hour figure for program development.

The Minicomputer System (IPC)

During the past seven months the efforts of the CAI Division of the Adult Learning Center have been concentrated on the development and testing of a minicomputer system for ABE instruction. Because of its differences from CAI, this system is referred to as an Instructional Process Controller (IPC).

If the hardware costs of computer assisted instruction are to be reduced to a level competitive with the costs of more conventional forms of instruction, the role of the computer in instruction must be reduced to its essentials. The larger the role the computer plays in instruction, the larger and more costly the hardware necessary to fulfill that role. Following the loss of the IBM 1500 System, the initial efforts of the CAI Division of the Adult Learning Center were directed to an analysis of the role of the computer in instruction and an attempt to rank the various computer functions in terms of their importance to instruction. A summary of these uses is given in Chapter 1.

The main outcome of this analysis was the decision that the critical computer use in instruction is feedback control. Essentially, all other computer uses in CAI could be performed by the pupil with minimal degradation of instructional effectiveness. Transferring these tasks to the pupil may introduce various inconveniences, such as the pupil having to keep track of his location in the program text; but within tolerable limits these inconveniences do not seriously interfere with the process of instruction. Feedback control, on the other hand, plays an essential role in the instructional process. If the pupil

is able to anticipate the correct answer on a frame, he will not go to the effort to generate that answer himself. The essential learning operations which give an instructional program its effectiveness as a learning tool will be short circuited and the learning will be degraded.

Furthermore, the feedback provided to the pupil in an instructional program is a primary motivational device. If the pupils' learning activities in the program are not strengthened by the feedback for responding, the activities will extinguish and the pupil will terminate his interaction with the program. If the pupil is physically restrained in the presence of the program, his interaction with the program will show long breaks and pauses if his activities are not under strong program control. The behavior of ABE pupils in the Learning Laboratory of the Adult Learning Center showed these long breaks and pauses when working on PI materials. The span of actual work on a PI course rarely exceeded 20 minutes and was usually only resumed after long breaks. Further, while working the pupil could be observed spending long amounts of time doing what would only be described as daydreaming. Their behavior was not very strongly under program control.

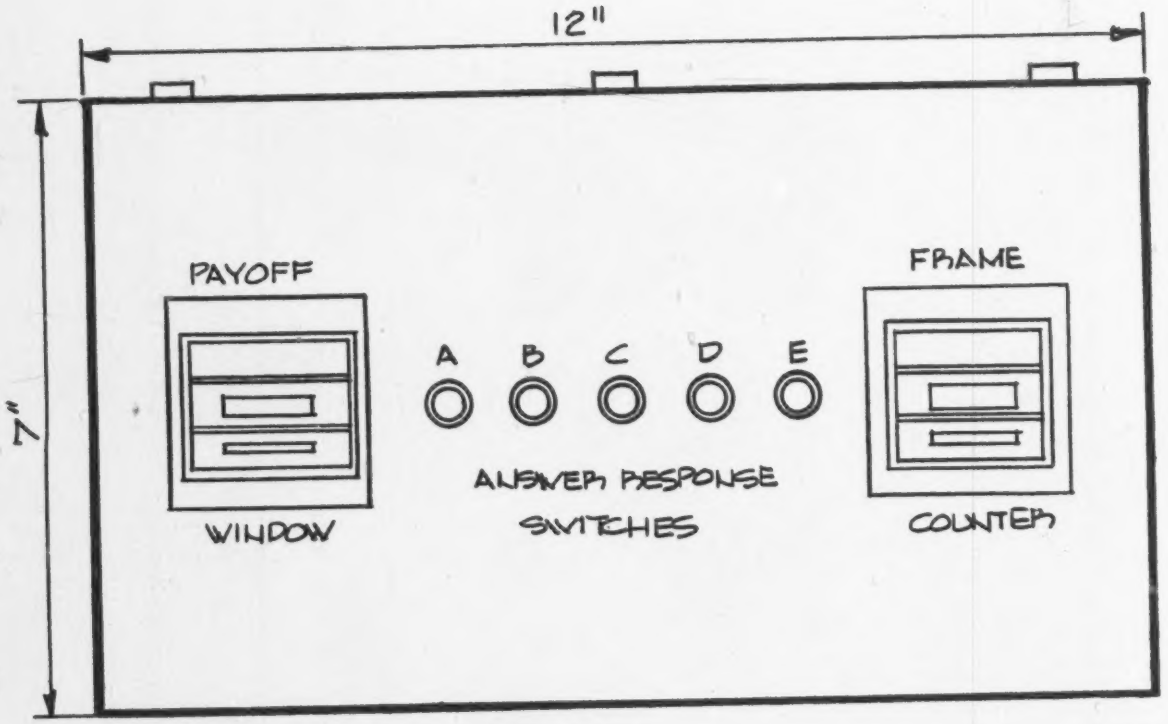
This poor behavioral control shown by most PI materials suggests a further function which may be introduced by computer control of response feedback. This feedback may be designed not only to provide informative feedback (confirmation or knowledge of results) but may augment the reinforcing properties of the feedback by delivering appropriate extrinsic reinforcers, such as money or other tokens redeemable for items of value.

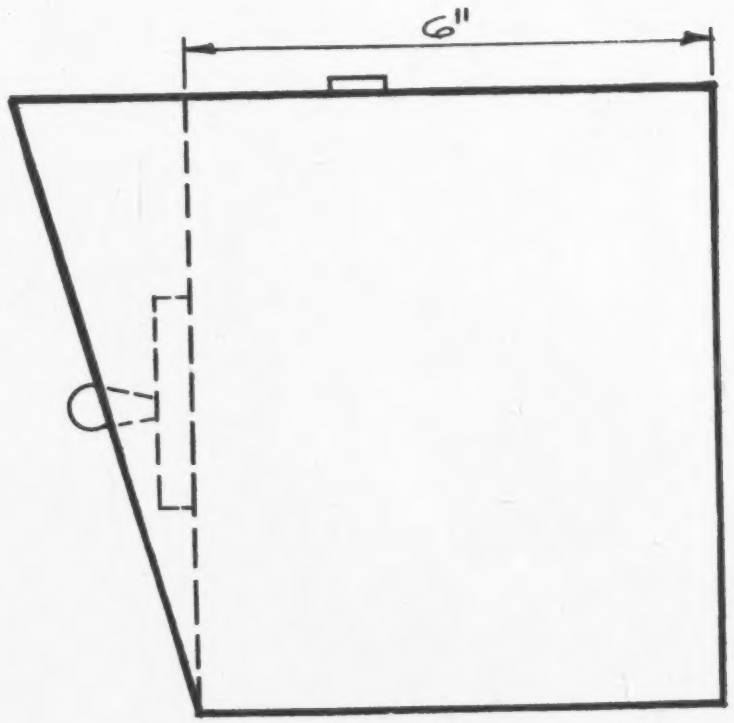
Thus the CAI Division of the Adult Learning Center decided to concentrate upon the use of computers in the control of feedback for pupil responses. All other instructional functions would be handled by more conventional means; books, manuals, paper and pencil operations, and proctor intervention in cases where remedial work was required.

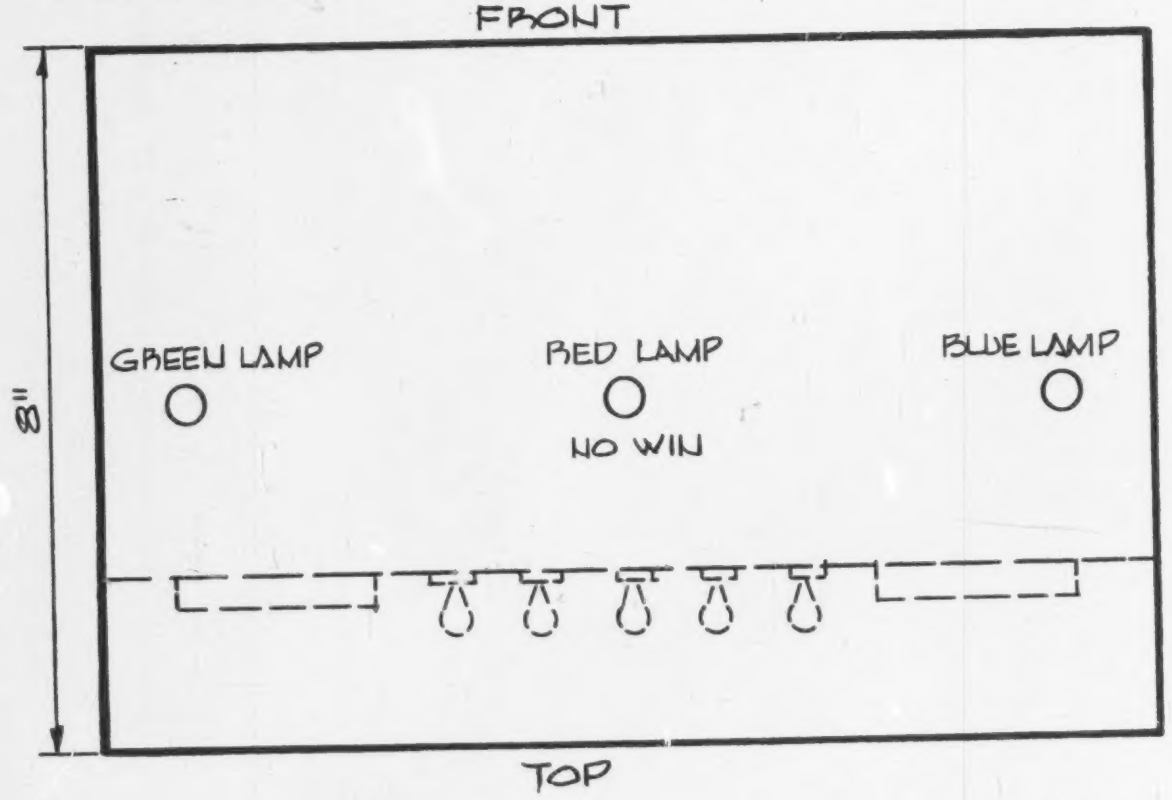
The basic instructional medium selected was Programmed Instruction. The course material was presented to the pupil in booklet form much like that of conventional linear programmed instruction, except that each called response was the selection of the correct response from a set of three to five choices given in the booklet, but the correct choice was <u>not</u> indicated anywhere in the booklet.

The pupil worked at a small desk on which was placed a small box for registering choices and for providing feedback (see Figure 1). This box contained five levers, two counters and three lights. One counter kept track of the frame the pupil was currently working on in the PI booklet. The other counter and lights were used to provide feedback to the pupil. When the pupil had worked through the current frame and selected the correct response, he would indicate his selection by pressing the corresponding lever on the student station. This station was controlled by a minicomputer which monitored the pupil's choice and determined the appropriate feedback. The lights and the feedback counter could then be used to provide various kinds of feedback to the pupil.

A series of pilot studies were run to determine optimum forms of feedback for controlling the learning activities of the pupil on the







STUDENT CONSOLE STATION

FIGURE 1

programmed text. The criterion used in evaluating various kinds of feedback was the persistence of the pupil in working at the programmed text.

In the developed version of the system, if the pupil's response was correct, immediate feedback was given indicating that the pupil was correct. (In some versions this feedback was augmented by a monetary reward displayed on the second counter). The frame counter advanced and the pupil could begin working on the next frame of the program.

If the pupil was incorrect, the central red light came on for one second and the pupil could select another response. The frame counter did not advance and the pupil could not respond to the next frame. If the second response was correct, the pupil received confirmation and whatever additional feedback that was programmed. The frame counter advanced and the pupil could proceed to the next frame.

If the second response was in error, the red light came on and stayed on. The pupil now could do nothing until his program was restarted by the proctor. When the red light locked on, this was also a call to the proctor to help the pupil. The proctor would then work with the pupil until his error was corrected and then advance the pupil to the next frame and restart his program.

The minicomputer controlled the feedback to the pupil for each response and stored each response and its latency in tenths of seconds. This is a small job for a computer. The machine used in this research was a Classic LINC computer with only 2K of memory and an eight microsecond cycle time. This is a small and relatively slow machine.

It was, however, easily able to simultaneously control four independent student stations and to store complete data for 50 frame programs. Printouts of pupil performance were then generated by the computer and printed on a teletype.

Using this highly simplified system, a number of studies have been run using various conditions of feedback and a number of different instructional programs. While these studies are not yet fully completed, the following preliminary observations may be reported:

(1) It was found that 10 minutes of instruction sufficed to make ABE pupils familiar with the operation of the IPC student stations. None of the anxiety generated by the IBM 1500 System was shown by any of the pupils tested. The pupils used in these studies were drawn from the Learning Laboratory of the Adult Learning Center and from ABE classes in Wake County, North Carolina. None had worked with the IBM 1500 System.

(2) Augmenting informative feedback by a monetary reward of 5¢ per correct response (about $1.60 per hour at the rate these pupils worked) provided strong control over pupil behavior. ABE pupils who are regarded by their teachers as problem students because they cannot concentrate will work and work without pause for one to one and a half hours on programmed instructional material that is at best of only marginal interest, e.g., programs on geography or monetary investments. They will work hard enough that they become conscious of fatigue in an instructional context for the first time in their lives.

(3) Under strong feedback control, stimulus control of the materials presented to the pupil is not necessary. During the pilot

studies the pupil's attention was strictly confined to the frame on which he was currently working, the one specified by the frame counter. In no case was the pupil observed turning to other portions of the program.

(4) When asked, pupils state that they prefer this mode of instruction to PI. Specific requests were generated by pupils in the Learning Laboratory to translate PI materials to the IPC format. The pupils state that they feel that they learn more and have to think harder to be successful on programs in the IPC format.

(5) Even for only moderately well-designed programs, the rate of proctor intervention is low. The proctor is engaged less than 25 percent of her time in working with four pupils. One proctor should be able to handle easily 16 pupils at a time. There is very little overlap in proctor calls from different pupils, even when most pupils are experiencing difficulty on the same frames, since the pupils are working at different rates.

(6) Proctor intervention permits immediate correction of pupil errors. A reasonable proctor possesses a flexibility in answering pupil problems that no computer program can match. This procedure combines the best aspects of programmed instruction and individual tutoring at low cost. The system also requires the proctor's intervention when the pupil experiences difficulties so that the pupil cannot compound his errors by failing himself to ask for help.

(7) Proctor intervention also permits immediate identification of the learning deficiencies of a pupil. By interacting with the pupil the proctor cannot only identify what the error is, but why the pupil

is making that error, whether it is an inability to pronounce certain key words or an inability to read a diagram or map or an inability to carry out a certain kind of computation. The pupil can then be given immediate remedial work by the proctor to make up that kind of deficiency.

(8) This procedure immediately identifies faulty frames in the programmed instruction. These will not only be identified as the ones with high error rates, but will be identified by the proctor working with the pupil who makes errors on the faulty frames. This procedure thus emerges as an ideal method for the development of programmed instruction.

(9) The cost of this system is low, both in hardware and in time for the development of the instructional program. Once the initial computer program is written, it will handle any instructional program simply by the insertion of the list of correct answers and will modify the form of the feedback simply by the selection of parameters at the start of the program. The development of the instructional materials is less costly than the development of similar PI materials because of the immediate validation and error detection described above. The hardware to operate 16 student stations costs less than $25,000, which gives a hardware cost of about $0.16 per pupil/hour. These costs make such a system price-competitive with any other means of instruction.

Research is currently in process on the effects of various kinds and levels of feedback on instruction and on the effects of various kinds of feedback delay on instruction. The system is also being used for the development of instructional materials specifically designed

to meet the needs of the ABE pupil. As this research is completed, it will be reported in further monographs in the ALCequel Research Monograph Series.

CHAPTER 4

SUMMARY AND RECOMMENDATIONS

The CAI Division of the Adult Learning Center has investigated the use of computers in the instruction of ABE pupils in two ways: (1) the use of an IBM 1500 System investigated the use of computers for testing, Drill and Practice and Tutorial-CAI, and (2) the development of an Instructional Process Control (IPC) System using a minicomputer and simplified student stations to control response feedback on programmed instructional materials.

(1) ABE pupils found the complexities of the student stations of the IBM 1500 System difficult to master and prone to produce anxiety. Typewritten response produced high error rates during learning. Any system failures produced strong negative emotional reactions on the part of the pupils.

To the degree that these difficulties were overcome, pupils were found to learn as well under Tutorial-CAI as under comparable PI. Tests given by the computer were found to have a reliability comparable to their paper and pencil versions, but scores were systematically lower on the computer versions. The cost of operating this system was found to be very high. CAI was not a preferred mode of learning for ABE pupils.

(2) The IPC System provided no impediments to learning. This system, used with an extrinsic motivator, produced sustained and concentrated learning activities. The proctoring system built into the operation of the IPC readily identified both learner deficiencies and

program deficiencies. Remedial work could be immediately undertaken in both areas. This system, which operates at low cost, shows promise of high instructional gains from the use of computers in the instruction of ABE pupils. This mode of instruction was preferred by ABE pupils to conventional PI.

As the result of its operations over the past four years, the Adult Learning Center CAI Division makes the following recommendations.

(1) CAI in its conventional forms should not be explored any further at present for ABE pupils. This recommendation is based on the following considerations: (a) Costs of instruction with CAI are at present too high to justify the use of such systems. (b) These costs will remain high until means are found to standardize instructional CAI programs so that they may be used freely with a mass audience. (c) The availability of a mass audience for ABE pupils is dependent upon wide distribution of currently expensive hardware, about $5,000 per student station including the costs of the central computing system. Until this investment is made, the mass audience to justify program development will not exist. (d) The current forms of student stations, centered about a CRT and keyboard, are not good interfaces for ABE pupils. The skills needed to operate the student stations are intimidating to ABE pupils and require rather extensive training. (e) Instructional gains over PI are not detectable. This makes it extremely difficult to justify the increased cost in both dollars and time required by CAI.

(2) Research should be supported to develop standardization in both peripheral hardware and computer software for CAI. Until this

standardization is achieved, cost-effective CAI is essentially impossible. Until this point is reached, further research on CAI is effectively blocked. The study of the effects on instruction of ABE pupils of the increased control over branching and over stimulus presentation in CAI must wait for the solution of this problem.

(3) Research should be supported for the development of more effective CAI student stations for ABE pupils. This is in part a human-factors problem and must take into account both the sensory disabilities of many ABE pupils and their information handling abilities for symbolic material. Current CAI systems do not meet these needs.

(4) Further demonstration programs should be supported to develop applications of the IPC System. This system is inexpensive in both time and dollars and in our pilot studies has shown important instructional gains. Our work at present has been able to explore only the surface of the applications of the IPC System to instructional problems. A proposal for investigation of the IPC as a device for the development of achievement motivation in ABE pupils has been submitted to the Office of Education. Work on additional aspects of the use of IPC is needed, i.e., its use as a testing device where testing can be conducted under constant motivational control, its use as a program development system, etc.

(5) Research should be supported for the development of mobile IPC systems. Because this system makes limited demands upon a computer, the total system can be housed in a single cabinet. It does not require any special environment as do larger computer systems. It then may be developed as a portable system which may be moved around to various

current ABE training centers. It may also, mounted in a trailer, be moved into the areas of maximum concentration of potential ABE pupils. By bringing instruction to the pupils, the capture ratio for ABE pupils may be significantly increased.

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